> Here we may give free rein to our imagination with the moral certainty that science will supply nothing tending either to prove or to disprove any of its fancies.

In this connection one is reminded of a famous apothegm,

> Faith is the substance of things hoped for, the evidence of things not seen.

George C. Comstock

QUOTATIONS

COOPERATIVE INDEXING OF SCIENTIFIC LITERATURE

We have shown that the core or *umbra* of a subject is comprised in a body of homogeneous literature which unquestionably can best be dealt with by its representative professional society, but that outside this core there exists a *penumbra* of relevant matter dispersed through a literature of gradually increasing irrelevance, with the result that the recovery of the relevant matter can be effected economically only by cooperative effort. The solution, therefore, would appear to be to bring into existence a central bureau which should deal solely with the indexing of periodicals of the non-homogeneous character—and in the first stages of its work, with a restricted list of periodicals assigned to it by the contributory bodies. These bodies would receive from the central bureau entries from the periodicals examined corresponding to their specified requirements. But as the professional abstracts became more fully representative of progress in their respective fields the need for the publication of the corresponding indexes would tend to disappear. The institution, therefore, of a central bureau would ultimately make for economy in all branches of science in which the publication of abstracts is admittedly indispensable.

So far as science is concerned, it will probably be found that the simplest and most effective method for obtaining the necessary index slips would be to invite the Central Bureau of the "International Catalogue of Scientific Literature" to provide them. Indeed, the possibility of cooperation between the "International Catalogue" and the abstracting journals was one of the subjects considered at the conference held last September. Any such arrangement would probably begin with the year 1921, and, as a preliminary, the "International Catalogue" should be brought up to date by the publication of volumes for 1915–20.—*Nature.*

SPECIAL ARTICLES

THE MOTIONS OF THE PLANETS AND THE RELATIVITY THEORY

Constant reference is made to the motion of Mercury about the sun and to the supposed fact that this motion can not be explained by the Newtonian law of gravitation. This current idea is far from correct: the motion of Mercury can be accounted for fully as well, if not far better, by the Newtonian law than by the Einstein law. The difficulty, which has faced mathematical astronomers for many years, is not how to account for the motion of Mercury, but how to account for that motion without introducing complications in the motions of the other planets.

In 1895 Newcomb[1] showed clearly that the motion of Mercury can be fully accounted for, under the Newtonian law, by one of several possible distributions of matter in the immediate vicinity of the sun and the inner planets. He, however, discarded each such possible explanation of the motion of Mercury because of the difficulties encountered in explaining, at the same time, the motions of the other planets. Each possible explanation of the motion of Mercury introduced a new complication somewhere else in the system.

Now identically the same difficulty is encountered by Einstein. His formulas account for the motion of Mercury, but fail to account for the motion of Mars, and introduce a further complication in the motion of Venus. The supposed explanation of the motion of Mercury by the Einstein formulas has been stressed, but the attendant difficulties in the motions of the other planets have been glossed

[1] "The elements of the four inner planets and the fundamental constants of astronomy," by Simon Newcomb.

TABLE I

Secular Motions of the Elements of the Four Inner Planets

	Observed	Computed	Difference	Per Cent.
PERIHELIA:				
Mercury	+ 579.2″	+ 537.6″	+41.6″ ± 1.4″	+ 7.2%
Venus	+ 42.4	+ 49.7	− 7.3 ±22.3	−17.2
Earth	+1161.5	+1155.6	+ 5.9 ± 5.6	+ 0.5
Mars	+1605.9	+1597.8	+ 8.1 ± 2.6	+ 0.5
INCLINATIONS:				
Mercury	+ 7.14″	+ 6.76″	+ 0.38″ ± 0.54″	+ 5.3%
Venus	+ 3.87	+ 3.49	+ 0.38 ± 0.22	+ 9.8
Mars	− 2.26	− 2.25	− 0.01 ± 0.14	− 0.4
NODES:				
Mercury	− 753.0″	− 758.1″	+ 5.1″ ± 2.8″	+ 6.8%
Venus	−1780.7	−1790.9	+10.2 ± 2.0	+ 0.6
Mars	−2248.9	−2249.8	+ 0.9 ± 4.6	+ 0.0

over by those who accept the relativity theory as proved.

In order to understand fully this question of the motion of Mercury and the difficulties of finding a satisfactory explanation, reference should be had to the secular motions of the elements of the planets, as determined by Newcomb. These motions are given in Table I.

The first column in the above table gives the actual motions in one century as determined from observations of the actual planets; the second column gives the corresponding motions as calculated by the formulas of celestial mechanics, deduced from the Newtonian law of gravitation. It is, however, well known to every mathematical astronomer that these calculations are not complete; that they do not take fully and completely into account all of the bodies of the solar system. In the theories and formulas upon which these calculations depend, the sun has been considered as a perfect sphere and all space between the sun and the various planets as free from all gravitational matter. These are necessary mathematical simplifications; without them the equations of motion would be impossible of solution. These simplifications approximate very closely to the truth and the results obtained by their use very closely represent the motions of the planets, but they are *approximations* and it, therefore, necessarily follows that the results do not accurately represent the actual motions.

The column of differences contains the unexplained portions of the motions of the planets, together with the "probable error" as determined by Newcomb. That is, in one century the perihelion of Mercury moves 41.6″ of arc more than the *approximate calculations* indicate it should; whilst that of Venus does not move quite as swiftly as these computations would lead one to expect. These unexplained portions of the motions are the so-called "discordances" or "discrepancies." That of the perihelion of Mercury is especially well known and has figured prominently in all attempts to prove false the law of Newton. The perihelia of Venus and Mars show large discrepancies, as do also the nodes of both Mercury and Venus.

The probable errors give some idea as to the relative accuracy of the various determinations, but it must be remembered that the assignment of these probable errors is very largely a matter of judgment, and that these values may have been over- or underestimated. In every step of the long and complicated computations an estimate, rather than an exact calculation, has to be made as to the value of the probable error, and the final value, as given in the table, thus depends upon many separate estimations or judgments.

It is known to every astronomer that the assumptions, upon which are based the simplifications used in the calculations, are not true. Neither the sun nor any one of the planets is a perfect sphere. The sun-spots, which

can be seen with an ordinary small telescope, show that the sun is not of uniform shape and density. While exact measurements of the shape of the sun are extremely difficult to make, yet every series of measures, heretofore made, show distinct departure from a true spherical form. The sun is not a sphere.

Passing outward from the sun itself one finds the corona. At times of eclipse this halo, or brilliant crown, about the sun can be seen by the unaided eye. It has been sketched many times; it has been photographed times without number. Its presence proves the sun to be surrounded by an envelope of matter of irregular shape and of vast size. This envelope is in general lens-shaped and it extends far out beyound the orbit of the earth. On clear dark nights the extreme outer portions of it can be seen after sunset as a faint glow in the western sky,—a glow that is well known under the name of the zodiacal light.

While matter is thus known to exist in the vicinity of the sun and the inner planets, yet its effect upon the motions of these planets cannot be accurately calculated. Until its distribution is fully known, its effect can not be reduced to figures. It is perfectly clear that the figure, 537.6″ per century, does not accurately represent the motion of Mercury's perihelion under the Newtonian law; but, in the present state of our knowledge as to the solar envelope, it is impossible to correct definitely this figure and to state finally what the true figure should be.

The whole question of the effect of this matter upon the motions of the planets has been made the subject of several recent investigations, notably by Jeffreys and Seeliger.[2] As the actual distribution of this matter is unknown, the problem is attacked in reverse: that is, from the discordances is found a general distribution of matter, which will account for the motions, and this calculated distribution is then compared with the known facts. This procedure is analogous to the method by which the planet Neptune was discovered.

The matter in the immediate vicinity of the sun would tend to group itself about a plane somewhere near that of the solar equator, or that of the orbit of Mercury; whilst matter at a considerable distance from the sun would tend more towards the invariable plane of the planetary system, which is nearly the same as that of the orbit of Jupiter. Further the density of the matter will decrease as the distance from the sun increases. This general distribution can be approximated to by assuming the whole mass to be made up of ellipsoids of revolution, each ellipsoid to be of uniform density, but the larger ones to be of much less density than the inner ones.

An ellipsoid, or ring, of matter wholly within the orbit of a planet will give a direct motion to the perihelion. But if the orbit actually lies in the matter composing such ellipsoid, then the effect is the opposite and the motion of the perihelion will be retrograde. This, of course, upon the assumption that the density is uniform throughout; if the density is much greater in the central portions of the ellipsoid, then the retrograde effect of the outer portion may be overcome and the total effect upon the perihelion may be direct, but the motion will be less than that due to the central portion alone. By adjusting the rate at which the density is assumed to decrease, any motion of the perihelion, direct or retrograde, within limits can be obtained. To changes in the density of the envelope surrounding the sun may thus be attributed the discordant motions of the perihelia of the four inner planets, and especially the retrograde discrepancy in the motion of Venus.

The entire mass of matter, which is known to exist, may for the purposes of computation be considered as made up of three ellipsoids, or as showing two abrupt changes in density. The small central dense portion lies wholly within the orbit of Mercury, the intermediate portion wholly within the orbit of the earth,

[2] "The secular perturbations of the four inner planets," by Harold Jeffreys, *Month. Notices, R. A. S.*, Vol. LXXVII., p. 112.

"Das Zodiakallicht und die emperischen glieder in der bewegung der planaten," by Seeliger.

De sitter, *Observatory*, Vol. XXXVI., 1913.

TABLE II

Final Discordances in the Secular Motions of the Elements of the Four Inner Planets

	Amounts to Account for Newcomb	Amounts Accounted for by			Final Discordances	
		Einstein	Seeliger	Poor	Einstein	Poor
Perihelia:						
Mercury	+41.6″	+42.9″	+41.7″	+41.6″	− 1.3″	+0.9″
Venus	− 7.3	+ 8.6	+ 7.3	− 7.5	−15.9	+0.2
Earth	+ 5.9	+ 3.8	+ 4.1	+ 5.9	+ 2.1	+ 0
Mars	+ 8.1	+ 1.3	+ 6.4	+ 6.9	+ 6.8	+1.2
Inclinations:						
Mercury	+ 0.38″	0	0	+ 0.37″	+ 0.38″	+0.01″
Venus	+ 0.38	0	0	+ 0.45	+ 0.38	−0.07
Mars	− 0.01	0	0	+ 0.12	− 0.01	−0.13
Nodes:						
Mercury	+ 5.1″	0	+ 5.4″	+ 4.9″	+ 5.1″	+0.2″
Venus	+10.2	0	+10.0	+ 9.1	+10.2	+1.1
Mars	+ 0.9	0	+ 7.2	+ 4.3	+ 0.9	−3.4

and the outer, or less dense, portion extends beyond the orbit of the earth nearly to that of Mars. The effect of each ellipsoid upon the perihelia, the nodes, and the inclinations of the planets can be found by simple formulas of celestial mechanics, and the positions and densities of those ellipsoids, which will best account for all the motions, can be determined. No distribution can be found that will rigorously satisfy all the motions, but the positions and densities of three ellipsoids can be found which will approximately satisfy all the equations and practically account for all the discordances in the motions of the planets.

The table given above shows with what a high degree of accuracy the motions of the planets can be accounted for under the action of this widely scattered matter. For purposes of comparison the Einstein motion is also given.

The relative probabilities of two theories, or two solutions of a problem, are usually determined from the final differences, or residuals, as these differences are called. That solution is deemed the more probable which makes the sum of the squares of the residuals the smaller. If this test be applied to the residuals as given in the above table, the results are:

Einstein theory	436
Solar envelope, Seeliger	259
Solar envelope, Poor	14

And these clearly indicate how very much more probable is the explanation of the motions of the planets as due to the presence of matter in space, than as due to the hypotheses of Einstein.

Einstein and his followers have cited the motions of the planets as proof of the truth of his hypotheses. The evidence does not sustain this—his hypotheses and formulas are neither *sufficient* nor *necessary* to explain the discordances in these motions. They are not *sufficient,* for they account for only one among the numerous discordances—that of the perihelion of Mercury; they are not *necessary* for all the discordances, including that of Mercury, can readily be accounted for by the action, under the Newtonian law, of matter known to be in the immediate vicinity of the sun and the planets.

It is, however, possible that the Einstein hypotheses be true, and that the discordant motions of the planets result from a combination of the Einstein motions and the effect of the widely distributed matter in space. Just as a definite distribution of matter can be found which will explain the discordances given by Newcomb, so also another and different distribution can be found that will more or less fully account for the discordances remaining after applying the Einstein effects. But it is clear that the relativity theory alone is not *sufficient* to explain the motions of the planets.

Thus the motions of the planets do not prove the *truth* of the Einstein theory, nor, on the other hand, do they prove its *falsity*. While these motions can be accounted for by a certain distribution of matter in the solar envelope, it has not yet been established by observation that the matter is actually distributed through space in the required way. The presence of the matter is unquestioned; its distribution is still a problem of observational astronomy. In the present state of our knowledge regarding the distribution of this matter throughout space, the motions of the planets do not and can not furnish a definite answer to the question as to the validity of the Einstein hypotheses of relativity.

CHARLES LANE POOR
COLUMBIA UNIVERSITY,
April, 1921

THE AMERICAN CHEMICAL SOCIETY

(*Continued*)

DIVISION OF ORGANIC CHEMISTRY

Rodger Adams, *chairman*
H. T. Clarke, *secretary*

Arsenated benzophenone and its derivatives: W. LEE LEWIS and H. C. CHEETHAM. Benzarsonic acid is best prepared by reduction of p-nitrobenzoic and arsenation by means of Bart's reaction. With phosphorus trichloride and pentachloride, dichloro-p-arsinobenzoyl-chloride results. By means of the Friedel and Crafts reaction, benzophenone-p-arsenious oxide, arsenious acid, and arsonic acid are formed. The similar derivatives of 4-methyl benzophenone-p-arsenious oxide, 4-methoxy benzophenone-p-arsenious oxide, and 4-phenoxybenzophenone-p-arsenious oxide have been prepared. Their nitro compounds, oximes, and isomers are being studied. With arsanilic acid, dichloro-p-arsinobenzoylchloride gives the di-arsenated benzanilide. The further reactions of dichloro-p-arsinobenzoylchloride with hydrocarbons, ethers, phenols, and various amino- and hydroxy-compounds are being studied.

6 chlorophenalphanapthazarsine and some of its derivatives: W. LEE LEWIS and C. S. HAMILTON. 6 chlorophenalphanapthazarsine is prepared by heating phenyl alpha naphthylamine with arsenic trichloride. 6 cholorophenalphanapthazarsine with hydrogen peroxide gives phenalphanapthazarsinic acid. The sodium salt of this acid has been prepared. A series of compounds, 6 methoxyphenalphanapthazarsine, 6 ethoxyphenalphanapthazarsine, 6 propoxyphenalphanapthazarsine, 6 butoxyphenalphanapthazarsine, 6 phenoxyphenalphanapthazarsine are prepared by treating 6 chlorophenalphanapthazarsine dissolved in xylene with the corresponding sodium alcoholate. 6 bromophenalphanapthazarsine is prepared by refluxing 6 phenalphanapthazarsine oxide or 6 phenoxyphenalphanapthazarsine with hydrobromic acid. 6 phenalphanapthazarsine oxide is prepared from 6 chlorophenalphanapthazarsine by heating with silver oxide.

Condensation reactions with benzyl cyanide: FRED W. UPSON and T. J. THOMPSON. Several phenyl alkyl succinic nitrils have been made by condensing benzyl cyanide either (1) with the cyanhydrine of the aliphatic aldehyde in the presence of sodium methylate, or (2) with the α brom ester of the fatty acid in the presence of sod-amide in ether suspension. Saponification of the resulting condensation products has given substituted succinic acids. The following have been made by method No. 2: methyl phenyl succinic acid, m.p. 185°; ethyl phenyl succinic acid, m.p. 194°; N. propyl phenyl succinic acid, m.p. 214°; and the following have been made by both methods: Iso-propyl phenyl succinic acid, m.p. 178°; iso-butyl phenyl succinic acid, m.p. 186°. The nitrils of the higher members can be saponified only under pressure. Some evidence has been obtained for the formula $C_6H_5—\overset{H}{C}=C=N—Na$ for the sodium salt of benzyl cyanide.

Derivatives of trihalogen tertiary-butyl alcohols. IV. The benzoic acid ester of tribromo-tertiary butyl alcohol or brometone benzoic acid ester: T. B. ALDRICH. The benzoyl ester of tribromo tertiary-butyl alcohol, $C_6H_5CO.OC—C_3H_6Br_3$, is prepared most conveniently by mixing molecular quantities of benzoyl chloride and preferably anhydrous tri-bromo tertiary butyl alcohol and heating on the steam bath until hydrogen bromide ceases to be given off. The ester is purified by heating on the steam bath with 5–10 per cent. caustic soda solution, washing with water, and finally recrystallizing from alcohol. It crystallizes in the monoclinic system and melts at 89–90°. It is readily soluble in the organic solvents, but insoluble in water. It is not so readily saponified as the aliphatic esters of either chloretone or bromotone. It is practically non-volatile at either incubator or room temperature, and is not volatile with steam to any extent. In general its properties are the same as the corresponding ester of trichloro-